

# DIRECT, NON-DESTRUCTIVE MEASUREMENT OF RECESS DEPTH IN A WAFER

5

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

10       The present invention relates to an effective, simple,  
direct and non-destructive method to measure recess depth in a  
wafer by putting the wafer into a track where a solvent is  
poured, commencement of spinning the wafer in the track to fill-  
up the recess, and subsequent spinning-off of the remaining  
15 solvent so that no solvent remains on the wafer surface, weighing  
the wafer, heating to remove the solvent, and again weighing to  
ascertain the difference in weight or the amount of solvent  
imbibed by the trenches together with solvent density, to permit  
a simple calculation of the recess depth.

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### 2. Description of The Prior Art

25       In the ASG and LOCOS resist or polysilicon recess process,  
control of the recess depth is crucial as the recess depth  
determines both parasitic leakage and the capacity of the  
transistor, thus controlling the storage time of the transistor.

30       At present, profiling techniques such as those performed  
with SEMs or AFM are used to monitor the recess depth within  
round or elliptical depths in a chip.

35       However, SEM measurements are time-consuming, costly and  
destructive. On the other hand, AFM measurements of recess depths  
in a trench is done in the kerf, in which the trench size is  
large enough to accommodate the bulky AMF tip. Because the recess  
depth is closely related to the size of the trench, a correlation

5 needs to be established between the large trench on the kerf and the real trench in the arrays.

U.S. Patent 6,275,297 discloses methods of and apparatus for measuring the depth of structures on a semiconductor substrate. The measurement is accomplished by a broadband light source that  
10 irradiates the recessed and non-recessed portions. A detector detects reflected light including a first spectral component comprising light reflected from the recessed portions and a second spectral component comprising light reflected from the non-recessed portions, wherein at least one of the first and  
15 second components further comprises a third component comprising light reflected from the dielectric layer. Spectral reflectance information of the detected rays is stored and a plot of reflectance intensity versus wavelength is generated. Depth geometries of the recesses and the dielectric layer are  
20 determined relative to the at least one reference interface based on an interferometric analysis of the plot.

An assembly for measuring a trench depth parameter in a work-piece is disclosed in U.S. Patent No. 5,691,540. The assembly comprises an ultra-violet radiation source; a split  
25 fiber bundle having a first branch for propagating the ultra-violet radiation from the radiation source to a lens, and a second branch; a lens for focusing the UV radiation to the workpiece and refocusing an ultra-violet interference signal to the second branch; and a detector responsive to the ultra-violet  
30 interference signal received through the second branch. The detector transforms the ultra-violet interference signal to an electrical signal which is a measure of a trench depth of the workpiece. The ultra-violet interference signal is developed when ultra-violet radiation propagates through the workpiece and  
35 reflects from its base region to thereby interfere with ultra-

5 violet radiation that is directly reflected by a workpiece surface which is different from the base region.

U.S. Patent 6,124,141 discloses a non-destructive method for measuring the depth at which the top surface of a buried interface is located in a semiconductor substrate. The method  
10 employs a Fourier Transform Infrared measurement, and comprises subjecting the semiconductor substrate containing the buried interface to a beam of infrared light and then detecting and analyzing the spectrum of a return signal by a Fourier analysis. The spectrum as analyzed by the Fourier analysis is then compared  
15 to calibration spectra to thereby determine the depth of the top surface of the buried interface. The invention also uses a device for determining the depth of a buried interface below the surface of a semiconductor substrate. That device comprises a FTIR spectrophotometer which illuminates the substrate with a source  
20 of infrared radiation and which produces a Fourier transform of a return signal reflected from the substrate. The device includes a library of stored calibration spectra, along with means for comparing the Fourier transform return signal to the calibration spectra to determine the depth of the buried interface.

25 U.S. Patent 4,840,487 discloses an apparatus for measuring etching pits by employing a light source having a small absorptivity with respect to a groove or pit as an object of irradiation to insure a satisfactory change in the interference intensity of the defracted light which is reflected from the  
30 object. The apparatus includes a detector means provided with the freedom of movement in two axial directions which are perpendicular to each other and in the direction of rotation. In addition, as a laser source, a He-Cd, N<sub>2</sub> or Ar laser may be employed in addition to a He-Ne laser to detect changes in their  
35 interference intensities, and the etch depth is calculated on the basis of the detected changes.

5        There is a need in the art of measuring recess depth in the  
wafer for an effective, simple, direct and non-destructive  
measurement technique for recess process control, especially with  
device dimensions of groundrule shrinkage to 0.13 microns and  
below, as the current profiling techniques are becoming  
10 increasingly more costly and difficult to correlate.

#### SUMMARY OF THE INVENTION

15        One object of the present invention is to provide an  
effective and non-destructive measurement technique for recess  
process control or depth measurement in a semiconductor chip,  
where the device dimensions or ground rules have shrunk to 0.13  
microns and below.

20        Another object of the present invention is to provide a  
simple, non-destructive measurement technique for recess process  
control or depth where the device dimension or groundrules have  
shrunk to 0.13 microns and below without employing SEM or AMF  
profiling techniques.

25        A further object of the present invention is to provide a  
direct, non-destructive measurement technique for recess process  
control or depth measurement in a semiconductor, where device  
dimension or ground rules have shrunk to 0.13 microns and below,  
that are less costly and less difficult to correlate.

30        In general, the effective, simple, direct and non-  
destructive method for measuring recess depth in a semiconductor  
chip of the invention is through the use of a solvent, and  
entails:

35        placing the recessed wafer into a track where a solvent is  
poured onto the wafer and commencing spinning of the wafer to  
recess the solvent into the trench and fill it up;

5       subsequently spinning off the remaining solvent so that no  
solvent remains on the surface of the wafer;  
          weighing the wafer;  
          heating to remove the solvent;  
          again weighing to ascertain the difference in the two  
10   weights or the amount of the solvent imbibed by the trenches; and  
          calculating recess depth premised around the density of the  
solvent and the weight difference.

15                   BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a Scanning Electron Micrograph of a typical wafer  
profile after resist recess and etching.

FIG. 2 is a schematic of the non-destructive method of  
20   measuring recess depth of a wafer utilizing a solvent in  
accordance with the invention process.

                  DETAILED DESCRIPTION OF PREFERRED EMBODIMENT OF THE INVENTION

25       Reference is now made to FIG. 1 which shows scanning  
electron micrographs (SEMs) of a typical wafer profile after  
resist recess and etching. The recess material Accuflow 913 EL  
from Honeywell. The POR resist recess etch recipe was applied to  
the wafer. From x-section pictures of the array center, and array  
30   edge, the most important data is collected; namely, the recess  
depth. In addition to the recess depth, information regarding the  
maximum variation is also collected, that is, the maximum  
variation within the wafer is 0.22 microns, within the array  
centers 0.11 micron and from the array center to the edge 0.14  
35   microns or smaller.

5 For a 110nm DRAM product, there is a 308 chips per 8 inches  
of wafer, and a half billion trenches per chip. Assuming that  
each trench has a width of 1.25nm, a length of 220 nm, and a  
depth of 1.3 microns, the total volume of trench that would have  
potential to be filled by a solvent is approximately  $4.3\text{mm}^3$ . The  
10 particular solvent utilized has a density or specific gravity of  
about  $1.4\text{g/cm}^3$ , and the weight difference is about 6mg. The  
balance scale utilized is easily capable of weighing up to 100g  
with a resolution of up to 0.05mg. This corresponds to less than  
1% noise level; in other words, easy measurement of a trench with  
15 recess depth of 1.3 microns can be made with an accuracy of up to  
13nm.

FIG. 2 is a schematic of the invention process for measuring  
the recess depth of a semiconductor chip. After recess, the  
wafers are put into a track where several mil of a solvent with a  
20 density of  $1.4\text{g/cm}^3$  is poured into the wafers, whereupon spinning  
is started. Because of the capillary force between the surface of  
the trenches and the solvent, the solvent easily recesses into  
the trench and fills it up. A subsequent spinning step is used to  
spin off the remaining solvent and render a wafer with trench  
25 filled with the solvent. However, at this juncture no solvent  
remains on the surface of the wafer. The wafer is weighted by a  
balance and then placed into a hot plate to remove the solvent by  
evaporation, whereupon the wafer is weighed again. The difference  
of the weight is the weight of the solvent imbibed by the  
30 trenches.

FIGS 2a to 2b depicts a wafer after it is put into a track  
and solvent is first applied, followed by commencement of  
spinning.

FIG. 2c depicts the wafer filled with the solvent.

35 FIG. 2d depicts the wafer after the second spinning process.

FIG. 2e depicts the wafer after it is put into a balance and weighted following removal of the solvent by heating to obtain weight W2.

The following calculations will show the amount the solvent  
10 that can be imbibed by 8 inches of wafer in the invention process:

The volume of one DT trench is

$$1.3\mu\text{m} * \text{Pi} * 125/2\text{nm} * 220/2 \text{ nm} = 2.8 \cdot 10^{-11}\text{mm}^3$$

The number of DT per wafer is  $308 \times 0.5 \times 10^9 = 1.54 \times 10^{11}$

15 The total volume of DT trenches per wafer is  $2.8 \times 10^{-11} \text{ mm}^3 \times 1.54 \times 10^{11} = 4.3 \text{ mm}^3$

Assume the density of solvent is  $1.4\text{g/cm}^3$ , the weight of the solvent that can be imbibed by trenches =  $4.3 \text{ mm}^3 \times 1.4\text{g/cm}^3 = 6.0\text{mg}$

20 The balance used can easily measure a 100g object with resolution up to 0.05mg.

The invention method takes advantage of capillary force between the surface of the trenches and the chosen solvent. Capillary force is the reaction between contacting surfaces of a  
25 liquid and a solid that distorts the liquid surface from a planar shape; it works very effectively in the size range of 1-100 microns.

The invention method is not limited to 110nm DRAM products or recess processes. The method is applicable to any process  
30 wherein there is a need to monitor the depth of huge numbers of trenches with relatively uniform depth across the wafers.